Chapter 9 Senses

I. **Sense** – the ability to perceive stimuli - the means by which the brain receives information about the environment and the body – is peripheral but actualized in the CNS – 2 group types
   A. **General Senses** – those with receptors *scattered* (distributed widely) over the body – 2 groups
      1. **Somatic** – provide information about the body and environment
      2. **Visceral** – provide information about internal organs (pain and pressure)
   B. **Special Senses** – specialized in structure and localized to a specific part of the body (i.e. smell, taste, sight, hearing and balance)

II. **General Senses** – include touch, pressure, pain, temperature, vibration, itch, and proprioception (sense of movement and position of body and limbs) – many of its receptors are associated with the skin
   A. **Receptors** – sensory nerve endings or specialized cells capable of detecting a stimuli by developing action potentials
      1. **Mechanoreceptors** – respond to mechanical stimuli – bending or stretching of receptor
      2. **Chemoreceptors** – respond to chemicals (smell & taste)
      3. **Photoreceptors** – respond to light (rods & cones)
      4. **Thermoreceptors** – respond to temperature changes
      5. **Nociceptors** – respond to stimuli resulting in pain
      6. **Proprioceptors** – respond to movement in muscles and tendons (i.e. golgi tendon apparatus & anyospiro – body position, stretch receptor)
   B. **Free Nerve Endings** – simplest and most common type of receptor – distributed throughout almost all parts of the body – some respond to pain, some temperature, some to itching, and some to movement – *hair follicle receptor mechanoreceptor that wraps around a hair follicle, detects light touch (see touch receptors)*
   C. **Temperature Receptors**
      1. **Cold receptors** – respond to decreased temperature – stop at temps below 12°C (54°F)
      2. **Hot receptors** – respond to increased temperature – stop at temps above 47°C (117°F)
   D. **Touch Receptors** – structurally more complex than free nerve endings – most are *encapsulated*
      1. **Merkel's disks** – superficial nerve endings located at the bottom of the epidermis, detect light touch and superficial pressure
      2. **Hair follicle receptors** – free nerve endings associated with the hair – mechanoreceptors wrapped around the hair follicle within the dermis – detect light touch
      3. **Meissner's Corpuscles** – located just deep to the epidermis – detect fine discriminative touch (tactile sensation) and light vibration
      4. **Ruffini's end organs** – located about middermis – detects continuous touch or pressure
      5. **Kreb's Corpuscles** – detects pressure (lips and tongue)
      6. **Pancinian Corpuscles** – located deep dermis – detects deep pressure and vibration – capsulated mechanoreceptor
   E. **Pain** – sensation characterized by a group of unpleasant perceptual and emotional experiences – 2 types

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1. **Superficial** – highly localized as a result of simultaneous stimulation of pain receptors and tactile receptors
2. **Visceral** – diffused pain (not localized) due to the absence of tactile receptors in the deeper structures – harder to diagnose the source/cause of the pain

F. **Anesthesia** – chemicals that block pain receptors – 2 kinds
1. **Local anesthesia** – chemicals injected near sensory receptors or nerves in a specific area, suppressing action potentials right at the source – ***no loss of consciousness*** – peripheral, localized
2. **General anesthesia** – injected chemicals, usually injected into circulatory system, resulting in suppression of the *reticular formation* (in the brain) creating a loss of consciousness – affects the CNS and whole body

* Pain can also be influenced by *inherent control systems*. ***Gate control theory*** – rubbing the area where the cause of the sensation is creates action potentials that inhibit pain action potentials that are carried to the brain by the lateral spinothalamic tract (disruption of action potentials in the spinal cord – other ways to produce this effect is with intense mental concentration or physical activity.

G. **Referred Pain** – the pain that is felt superficially as a result of tissue damage of an internal organ (i.e. pain felt in the left arm as a result of an occurring heart attack) – clinically useful in diagnosing actual cause of pain

H. **Phantom Pain** – occurs in amputees' – feeling of pain or itching in a limb that is no longer there – caused by stimulation of axons that were severed that the brain knows ***should*** originate in the severed limb

III. **Special Senses** – 5 highly localized, special senses

A. **Olfaction** (smell) – chemoreception - occurs in response to airborne molecules, *called odorants*, that enter the nasal cavity and dissolve in mucus covering the surface of the epithelium lining the nasal cavity – ***bipolar olfactory neurons*** lie within the epithelium lining the superior portion of the nasal cavity – the ***axons*** of these neurons extend up through the ***cribriform plate*** of the ethmoid bone, these axons help to form the olfactory nerve, and synapse with interneurons in the ***olfactory bulb*** which sends action potentials down the ***olfactory tract*** to the ***olfactory cortex*** located in the temporal and frontal lobes of the brain – the ***dendrites*** of these *bipolar olfactory neurons* extend down into the mucus, of the nasal cavity, where the dissolved odorants bind to receptor sites on the dendrites starting the action potential – ***sensory fatigue*** or ***odor adaptation*** occurs when ***all*** of the receptor sites on the *dendrites* are bound by dissolved odorants making it impossible for any new action potential to start

B. **Taste** – chemoreception, strongly linked to olfaction due to the joining of nasal and oral cavities via the pharynx – action potentials mostly carried by the *Facial Nerve* (VII), some by *Glossopharyngeal* (IX) and *Vagus* (X) – occurs in response to molecules and/or ions dissolved in saliva triggering action potentials in ***taste buds*** located on the surface of certain papillae throughout the epithelium lining the oral cavity, pharynx, and covering the tongue & epiglottis – each taste bud consists of 2 types of cells
1. Specialized epithelium forms the *exterior* supporting capsule
2. *Interior* consists of about 40 ***taste cells*** – each containing hair like processes called ***taste hairs*** (gustatory bipolar neurons) that extend into a tiny opening in the surrounding epithelium (taste pore) – dissolved molecules or ions attach to receptors on the *taste hairs* initiating action potentials that are carried by sensory

neurons to the medulla → then the thalamus → then the ***gustatory cortex*** which is located in the *parietal lobe* of the cerebral cortex

3. **Five basic tastes**
    a. **Sour – taste buds concentrated mostly on the posterior, lateral portion of the tongue**
    b. **Salty** – taste buds concentrated mostly on the *anterior, lateral* portion of the tongue
    c. **Bitter** – taste buds concentrated mostly on the *posterior* (back) portion of the tongue
    d. **Sweet** – taste buds concentrated mostly on the *anterior* (tip) portion of the tongue
    e. **Umami** – described as a meaty, brothy, or savory

*FYI 2 other tastes found are ***alkaline*** and ***metallic***

C. **Vision** – system converts light energy into nerve impulse – includes; eyes, accessory structures and sensory neurons
    1. **Accessory structures** – protect, lubricate, and move the eyes
        a. **Eyebrows** – protect by keeping perspiration out of the eyes and shading the eyes
        b. **Eyelids and lashes** – protect by keeping foreign particles out of the eyes – help to lubricate by moving lubricant over the eyes (blink reflex)
        c. **Conjunctiva** – thin transparent mucus membrane that's *highly vascular,* covering the inner surface of the eyelids and the anterior surface of the eyes – also has lots of nerves – consists of stratified columnar epithelium (rare) with lots of goblet cells – *conjunctivitis (pink eye)is inflammation of this membrane*
        d. **Lacrimal Apparatus** – main function is to produce ***tears*** which wash the eye of foreign material and contain as enzyme that combats infection – consist of the following
            - **Lacrimal gland** – exocrine gland the size of an almond, produces tears due to *parasympathetic* stimulation by Facial Nerve (VII)
            - **Lacrimal ducts** – extend from the lacrimal glands and carry tears to the surface of the eyes
            - **Lacrimal canaliculi** – small canals that collect the tears after they have washed over the eye located in the medial corner of the eye
            - **Lacrimal sac** – the enlarged, superior portion of the *nasolacrimal duct* that the lacrimal canaliculi empty into
            - **Nasolacrimal duct** – carries any foreign material and tears from the lacrimal sac and empties into the nasal cavity
        e. **Extrinsic Eye Muscles** – 6 skeletal muscles responsible for movement of the entire eye – 4 of the muscles attach to the 4 quadrants of the eye (superior, inferior, medial, and lateral *rectus* muscles) and 2 are located at an angle to the long axis of the eye (superior and inferior *oblique* muscles)
    2. **Anatomy of the Eye** – the eye is a hollow, fluid filled sphere consisting of 3 tunics and 3 chambers
        a. **Fibrous tunic** - consists of two parts
            - **Sclera** - the firm white outer connective tissue layer of the posterior 5/6ths – helps maintain shape, protects internal structures, and provides attachment sites for *extrinsic* muscles

- **Cornea** – the transparent anterior 1/6th – permits light to enter and bends/refracts light (part of focus) – consists of stratified squamous epithelium with dense regular connective tissue consisting of collagen fibers

b. **Vascular tunic (uvea)** – layer containing most of the blood vessels – consists of 2 areas continuous with each other and associated with the ***sclera*** *&* ***cornea***
   - **Choroid** – posterior portion associated with the *sclera* – very thin structure containing a vascular network and many *melanocytes* that produce *melanin* (a black pigment which absorbs light reducing reflection)
   - **Cilliary body** – anterior portion, continuous with the *choroid* – contains 2 sets of smooth muscle (*intrinsic cilliary muscles; [1]circular or papillary constrictor muscle is ran by parasympathetic stimulation only and is responsible for making the* ***pupil*** *(which is a hole/opening) smaller (allowing less light in)when contracted, [2]radial or papillary dilator muscle run by sympathetic stimulation only and is responsible for widening the pupil (by pulling the edges back when contracting) to allow more light in, * both run by III Oculomotor Nerve*) which attaches to the perimeter of the ***lens*** (a biconvex, flexible, transparent disc consisting of dense regular fibrous tissue, primary driver on focus/refraction of light – ***not part of the tunic***) by ***suspensory ligaments*** (hold the lens in place and are part of the mechanism to pull/flatten the lens or relax/thicken the lens)- the ***iris*** (colored part of the eye) is attached interiorly to the *cilliary body*

*When the lens is flat it's focused for *far* sight. When the lens is thick (more spherical) it's focused for *near* sight – ***accommodation*** is adjusting from far to near or vice versa – ***consensual light reflex*** is when both eyes (pupils) respond when light is shined in one (indication of brain damage if only one responds)

c. **Nervous tunic (retina)** – inner most tunic covering the posterior 5/6ths of the eye and is bilayered
   - **Pigmented retina** – the outer layer - is black, along with the *choroid*, keeping light from reflecting back into the eye
   - **Sensory retina** – the inner layer – contains ***photoreceptor cells*** (***rods*** *(responsible for black & white vision – 20x more than cones)*and ***cones*** *(responsible for color vision – 3 types; blue, green, and red)* - which respond to light) and numerous interneurons
     - The posterior portion of the *retina* has 2 major features: [1] ***macula lutea*** – small yellow spot at the center of the posterior retina, consisting mostly of *cones* – the center of this is called the *fovea centralis* – which is the point of sharpest vision and consists of only *cones*; [2] ***optic disc*** – just medial to the *macula lutea* it is the point where the nerve fibers (ganglion axons) exit to form the *optic nerve* and the blood vessels enter/exit – *there are* ***no*** *rods or cones in this area which creates a* ***blind spot***

Function of Rods and Cones:** Rods (most common *photoreceptor – approx 130 million, activated by 40% less light than cones, 2000 folds of cell membrane)* contain a photosensitive pigment called ***rhodopsin (visual purple) which is made up of a colorless

protein enzyme called ***opsin*** (globular protein located in the phospholipid bilayer of the cell membrane) and ***retinal*** (yellow pigment) in loose chemical connection. When light strikes the *rod* it causes a shape change in the *retinal* portion of the rhodopsin which in turn causes a shape change in the *opsin* causing the two to lose their loose chemical connection (photo isomerism) → the retinal goes to the choroid where it is changed back to it's attachable state → it is then reattached to the opsin (this requires ATP). In the dark the rods have open ligandgated sodium (Na^+) channels (bound ligand is *cyclic quanosine monophosphate (cGMP)*) that allow a continual flow of sodium into the cell, at the same time the sodium-potassium-pump ($3Na^+$ out $2K^+$ in) is working, creating what's called the ***dark current***, causing a constant state of depolarization (-40mv) → this in turn causes secretion of a *inhibitory* neurotransmitter (glutamic acid) which ***inhibits*** the *bipolar interneuron* from releasing it's neurotransmitter. When light causes the shape changes to occur in *rhodopsin* the enzyme portion *opsin* is activated which catalyzes a cascade reaction of 3 reactants with the product of these three breaking down the cGMP there by closing the ligandgated Na^+ channels, however, the sodium-potassium-pump is still going and shifts the membrane voltage toward -70mv – this causes the rod to stop secreting glutamic acid, *hyperpolarizing* the *bipolar interneuron* and causing it's release of a neurotransmitter, stimulating the ***ganglion cell*** (only retinal cell that *produces* an action potential) – this process is the ***light current***. Tremendous amount of convergence – 600 rods converge with each bipolar interneuron and 100 of these with each *ganglion cell.* Cones, approx 6.5 million, have a similar photosensitive component to rhodopsin called ***photopsin*** (iodopsin) – only difference is the amino acid sequence in the *opsin* (the retinal is the same and functions the same) – 3 varieties; ^{1} blue light, ^{2} red light, ^{3} green light

d. **Anterior Chamber** – the space located between the *cornea* and the *iris* – filled with ***aqueous humor*** (watery fluid) which helps to maintain eye pressure, bends (refracts) light, provides nutrients to the inner eye surfaces, is produced by the *cilliary body*, is a clear blood filtrate, is returned to the venous system by the ***canal of Schlemm*** (which drains into the scleral venous sinus) and a venous ring surrounding the cornea, and is exchanged every 90 min
e. **Posterior Chamber** – the space between the *iris* and the *lens* – also filled with *aqueous humor* which flows into the *anterior chamber* through the *pupil*
f. **Vitreous Chamber** – the space between the *lens* and the *retina* – filled with ***vitreous humor*** - a transparent jelly-like substance which helps maintain eye pressure, holds the *lens* and *retina* in place, gives the eye it's shape, refracts light, is formed prenatally of proteoglycans, and ***does not flow***

*Proprioception – proprioceptors associated with the extrinsic eye muscles provide depth perception

3. **Refraction** – bending of light – starts at the *cornea* → *aqueous humor* → *lens* (most refraction occurs here) → *vitreous humor* → to the *retina*
4. **Neural Pathways**
   a. **Optic Nerves** – axons of ganglion cells bundled together leaving the eye at the *optic disc* – (2) right and left
   b. **Optic Chiasma** – the joining and reorganizing of the *optic nerves* (from the right and left eyes) immediately inferior to the hypothalamus and anterior to the pituitary
   c. **Optic Tracts** – the reorganized axons, of the *optic nerves*, that extend from the *optic chiasma*, in bundles, to the right and left hemispheres of the brain

d. **Thalamus** – most of the axons terminate here (synapse with neurons of *optic radiations*) in the ***lateral geniculate nucleus*** – some separate out, extending off the *optic tracts*, to terminate in the ***superior colliculi*** (center for *visual reflexes of the extrinsic eye muscles*) and ***pretectal nuclei*** (involved in photopupillary and accommodation reflexes) located in the midbrain
e. **Optic Radiations** – the neurons of these axons arise in the *lateral geniculate nucleus* and extend to the ***visual cortex*** (located in the *occipital lobe*, is where signals (action potentials) are perceived (interpreted))

D. **Hearing & Balance** – divided into 3 parts; external, middle, and inner ear – external and middle ear function in hearing only – inner ear functions in hearing and balance
1. **External Ear** – extends from the *auricle* through the *external auditory meatus* to the *tympanic membrane*
   a. **Auricle** – also called the ***pina***, is the fleshy outer ear that collects the *sound waves* (changes in air pressure)
   b. **External Auditory Meatus** – flesh lined canal, in the temporal bone, containing hair and *ceruminous glands* (produce cerumen (ear wax) which keeps foreign objects out of the inner ear (protection)) and carries *sound waves* on
   c. **Tympanic Membrane** – thin membrane separating external and middle ear – vibrates when *sound waves* reach it
2. **Middle Ear** – an air filled cavity with 2 covered openings, 2 uncovered openings, and 3 small bones, ***auditory ossicles*** (malleus, incus, and stapes), that magnify vibration by approx 20x
   a. **Oval Window** – covered opening into the inner ear – covered by the *stapes* – carries sound in
   b. **Round Window** – covered opening that absorbs *sound waves* after they have traveled through the inner ear
   c. **Mastoid Opening** – open airway into the mastoid air cells of the mastoid process – helps maintain air pressure
   d. **Auditory Tube (Eustachian tube)** – opens into the nasopharynx – enables air pressure to be equalized between the outside and middle ear
   e. **Malleus (hammer)** – attached to the medial side of the *tympanic membrane* – transmits *sound wave* vibrations to the *incus*
   f. **Incus (anvil)** – connected by a small synovial joint to the *malleus* – transmits *sound wave* vibrations to the *stapes*
   g. **Stapes (stirrup)** – smallest *auditory ossicle* (smallest bone in the body) – connected by a synovial joint to the *incus* – the base of this bone is seated in the *oval window* and surrounded by a flexible ligament – transmits *sound wave* vibrations to the inner ear
3. **Inner Ear** – consists of interconnecting tunnels and chambers with-in the temporal bone; ***bony labyrinth*** (is divided into 3 regions; cochlea (involved in hearing), *vestibule*, and *semicircular canals* (both involved in balance)) along with the ***membranous labyrinth*** (a set of membranous tunnels and chambers) are filled with fluid
   a. **Perilymph** – fluid between the *bony labyrinth* and *membranous labyrinth*
   b. **Endolymph** – fluid with-in the *membranous labyrinth* – predominant ion being potassium (K^+)
4. **Hearing & the Cochlea** (a snail shaped organ where hearing is produced)
   a. **Spiral Lamina** – the spiral threads of the *cochlea*

- **Scala Vestibuli** – starts at the *oval window* (where sound waves enter) and winds its way through the *spiral lamina* to the apex where it becomes the *scala tympani*
- **Scala Tympani** – starts at the apex of the *spiral lamina* and winds its way back through the *spiral lamina* to the *round window* (where sound waves exit/are absorbed)

b. **Organ of Corti** – a spiral organ that winds its way through the middle of the *spiral lamina* – is the divider between the *scala vestibuli* and *scala tympani* in the *cochlear duct* – contain *hair cells* associated with axon terminals of sensory neurons that are located in the ***cochlear ganglion*** (spiral ganglion)
- **Cochlear Duct** – space between the *vestibular membrane* (simple squamous epithelium with a basement membrane and a little connective tissue) and the *basilar membrane* (thickness varies along the *cochlear duct* – bodies of the hair cells rest against this) – these two membranes make up the membranous labyrinth and are filled with endolymph
- **Tectorial Membrane** – a cellular gelatinous shelf attached to the *spiral lamina*, with-in the *cochlear duct*, and associated to the *organ of corti* because the *microvilli* of the *hair cells* being embedded in this membrane
- **Hair Cells** – contain mechanically gated potassium channels with ***tip links*** (potassium rushes in depolarizing the cell – have **no** axons of their own – are associated with axon terminals of sensory neurons located in the ***cochlear ganglion*** (spiral ganglion), these axons join to form the ***cochlear nerve***, which then joins the ***vestibular nerve*** to form the ***Vestibulocochlear Nerve*** (VIII) cranial nerve

5. **Sound Wave Conduction** – sound waves (changes in air pressure) are collected by the *auricle* and directed down the *external auditory meatus*, then strike the *tympanic membrane* making it vibrate causing the *auditory ossicles* to vibrate – the vibrations then pass to the inner ear by way of the *stapes* vibrating in the *oval window* causing the perilymph to vibrate, displacing the *basilar membrane* and *tectorial membrane*, also *endolymph* vibration which causes the bending (mechanical movement) of the *hair cells* creating an action potential to be generated in the axons of sensory neurons which then travel on down the *cochlear nerve* and so on
   a. **Pitch** – caused by the ***area*** in which the *basilar membrane* distorts (because the *basilar membrane* is denser near the oval window, higher pitches distort it in that area vice-versa the basilar membrane is narrower near the apex so lower pitches distort it in that area)
   b. **Volume** – is a function of sound wave *amplitude* (causes the *basilar membrane* to distort more intensely in the area of the pitch)
6. **Neuronal Pathways (Hearing)** – cochlear nerve bodies located in the *cochlear ganglion* send axons to the ***cochlear nucleus*** in the brain stem – cell bodies there then project axons to other areas including the ***inferior colliculus*** (in the midbrain) which project fibers to the ***thalamus*** then on to the ***auditory cortex*** located in the temporal lobe of the cerebrum
7. **Balance (Equilibrium)** – has 2 components
   a. **Static Equilibrium** – associated with the *vestibule* – involved in evaluating the position of the head relative to gravity – 2 chambers of the vestibule: *utricle* and the *saccule* – each containing specialized patches of epithelium, *maculae* which contain *hair cells* with microvilli embedded in a gelatinous mass weighted by *otolithes* (particles composed of protein and calcium carbonate) – this mass moves in response to gravity bending the microvilli of

the *hair cells* which initiates an action potential in the associated neurons – these action potentials are carried by the *vestibular nerve* (which joins the *cochlear nerve* to form the *Vestibulocochlear* (VIII) cranial nerve) to the *vestibular nucleus* located in the cerebrum for interpretation of head position

b. **Kinetic Equilibrium** – associated with the *semicircular canal* – involved in evaluation of change in direction and speed of head movements – 3 canals at nearly right angles to each other to detect movements in any direction – the base of each canal is expanded into an *ampulla* which contains specialized epithelium, *crista ampullaris*, consisting of a ridge of epithelium with a curved of gelatinous mass suspended over the crest called a *cupula* which is surrounded by endolymph – the hair like microvilli of the *crista ampullaris* hair cells are embedded in the *cupula* which acts as a float that is displaced by the endolymph movement with-in the canals – when the head moves in a given direction the endolymph tends to remain stationary while the *cupula* moves with the head – this bends the microvilli depolarizing the hair cells which causes an action potential to be generated in the axon terminals of the associated vestibular nerves